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(54) Title: A WIRELESS COMMUNICATIONS CELLULAR ARCHITECTURE FOR IMPROVING COMMUNICATIONS RESOURCE ALLOCATION

(57) Abstract

A method and apparatus for communications resource allocation in a wireless communications system having a total system bandwidth. A service area is divided into a plurality of sectors. A first set of base station antennas are positioned within a first set of sectors. The first set of antennas have main beams set at a first set of angles, and each antenna corresponds to a sector within the first set of sectors. A second set of base station antennas are positioned within a second set of sectors adjacent to the first set of sectors. The second set of antennas have main beams set at a second set of angles, and each antenna corresponds to a sector within the second set of sectors. Each sector is assigned a portion of the total system bandwidth.

# A WIRELESS COMMUNICATIONS CELLULAR ARCHITECTURE FOR IMPROVING COMMUNICATIONS RESOURCE ALLOCATION

5 FIELD OF THE INVENTION

The invention relates to wireless systems. More particularly, the invention relates to a method and apparatus for assigning communications resources for a 10 wireless communications system.

BACKGROUND OF THE INVENTION

The demand for wireless communications services is 15 on the rise. Cellular telephones are becoming as common as office and residential telephones. Personal Communications Service (PCS) offers the potential to improve existing cellular communications dramatically. Wireless high-speed broadband packet services hold 20 promise for a whole host of new services for work-at-home, telecommuting, local and Internet access.

As a result of the increased popularity of wireless communications services, bandwidth demands for wireless systems providing these services have 25 increased accordingly. Bandwidth refers to the difference between the two limiting frequencies of a band expressed in Hertz (Hz). Bandwidth is a key limiting factor in determining the capacity of the system. The term "capacity" loosely refers to the 30 number of users a system can service, or the amount of information a system can transmit to a user at any one time.

A traditional solution for increasing the

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bandwidth efficiency in wireless systems is through
frequency reuse. Frequency reuse refers to reusing a
common frequency band in different cells within the
system. The concept of frequency reuse will be
5  discussed in more detail with reference to FIGS. 1 and
2.

FIG. 1 is a diagram of a typical wireless
communication system suitable for practicing the
10  present invention. FIG. 1 shows a base station 20 in
wireless communication with terminal stations 22. Base
station 20 is connected to a Mobile Switching Center
(MSC) 26. MSC 26 can be connected to a fixed network,
such as the public switched telephone network (PSTN) 24
15  shown in FIG. 1 or the Internet (not shown). MSC 26
may also be connected to other base stations (not
shown). Terminal stations 22 can be either fixed or
mobile.

Base station 20 communicates information to/from
20  terminal stations 22 using radio signals transmitted
over a range of carrier frequencies. Frequencies
represent a finite natural resource, and are in high
demand. Moreover, frequencies are heavily regulated by
both Federal and State governments. Consequently, each
25  cellular system has access to a very limited number of
frequencies. Accordingly, wireless systems attempt to
reuse frequencies in as many cells within the system as
possible.

To accomplish this, a cellular system uses a
30  frequency reuse pattern. A frequency reuse pattern is
determined by taking the total frequency spectrum
allotted to the system and dividing it into K sets of
frequencies, with each cell having access to one set of

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frequencies.  For example, if the system were allocated
70 MHZ of frequency spectrum, and there were 7 sets of
frequencies (K = 7), each set would include 10 MHZ
worth of the 70 MHZ available to the system (assuming a
5    uniform distribution).  Thus, each cell would have
access to 10 MHZ worth of the total frequency spectrum
allotted to the system.

FIGS. 2(A) through 2(D) illustrate examples of
frequency reuse patterns corresponding to K = 4, 7, 12
10   and 19, respectively.  A cellular communication system
has a number of communication sites located throughout
the geographic area served by the system.  As shown in
FIGS. 2(A) through 2(D), a geographic area can be
organized into cells and/or sectors, with each cell
15   typically containing a plurality of communication sites
such as a base station and terminal stations.  A cell
is represented in FIGS. 2(A) through 2(D) as a hexagon.
FIG. 2(A) shows a frequency reuse pattern where K = 4.
Cells are placed into groups of four (referred to as a
20   "cluster"), with each cluster employing one of the
frequency sets 1 through 4 (the number within each cell
in FIG. 2(A) represents a set of frequencies).  This
cluster of four cells is then repeated until the entire
service area is covered.  This same pattern is shown in
25   FIGS. 2(B), 2(C) and 2(D) for clusters of 7, 12 and 19
cells, respectively.

In view of the above, it can be appreciated that
the larger the frequency reuse factor (i.e., K), the
smaller amount of frequency is available to each cell.
30   This limits the overall capacity of the system, for
example, by limiting the number of terminal stations
that can communicate within a cell, or the data rates
at which each terminal station can send and receive

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information. Consequently, to the extent that the
frequency reuse factor (<u>i.e.</u>, K) can be lowered, the
more capacity the system has to offer wireless
communications services.

5          A major factor in designing a frequency reuse
pattern is the attempt to maximize system capacity
while maintaining an acceptable signal-to-interference
ratio (SIR). SIR refers to the ratio of the level of
the received desired signal to the level of the

10    received undesired signal. Most of the undesired
signal is due to co-channel interference. Co-channel
interference is interference due to the common use of
the same frequency band by two different cells. Thus,
to a large extent, co-channel interference determines

15    how often a set of frequencies may be reused throughout
the entire system. Accordingly, to the extent co-
channel interference can be minimized, the lower the
frequency reuse factor (<u>i.e.</u>, K).

          In an attempt to minimize co-channel interference,

20    conventional systems have separated each cell into
multiple sectors, with each sector having a directional
antenna co-located with a base station at the center of
the cell. The beamwidth of each base station antenna
is normally wide enough to cover the whole sector.

25    Typically, a cell is divided into three sectors with
each sector having a 120 degree antenna. These cell
configurations, however, are unsatisfactory for a
number of reasons, which are described with reference
to FIGS. 3, 4, and 5.

30          FIG. 3 is a diagram of a conventional three-sector
cell. The cell is represented as a hexagon, with solid
lines representing hypothetical cell contours. The
term "cell contours" refers to the outline of a cell as

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well as the lines within a cell which define a sector.
The cell has a base station located at the center of
the cell, with a directional antenna covering each
sector of the cell.   The beamwidth of each base station
5      antenna is 120 degrees.   The analytical cell contours
(i.e., coverage area for each antenna transmission
beam) is represented by non-solid lines.   As shown in
FIG. 3, the analytical cell contours for the front lobe
of the antenna transmission beam for sector 1
10      ("originating sector") forms the shape of an oval.  The
hypothetical cell contours for sector 1, however, forms
the shape of a diamond.   As a result, it can be
appreciated that the analytical cell contours do not
match the hypothetical cell contours.   Consequently,
15      the analytical cell contours overlap into the sectors 2
and 3 which are adjacent to sector 1, thereby
interfering with the antenna transmission beams for
sectors 2 and 3.   This type of cell configuration is
referred to hereinafter as a wide-beam trisector cell
20      (WBTC).

FIG. 4 illustrates a frequency reuse pattern with
K = 4 using conventional three-sector cells.   Cells are
placed into a cluster of four, with each cluster
employing one of the frequency sets 1 through 4.   This
25      cluster of four cells is then repeated until the entire
service area is covered.   It can be appreciated that if
each cell is a WBTC, the analytical cell contours
illustrated in FIG. 3 will overlap not only with
sectors adjacent to the originating sector within the
30      same cell, but also to sectors adjacent to the
originating sector in other cells (hereinafter
collectively referred to as "adjacent sectors").   The
increased interference caused by overlapping

transmissions increases the frequency reuse factor, thereby decreasing overall cell and system capacity. FIG. 4 also illustrates that the distance (D) between each base station using conventional three-sector cells

5    is 3.5 times the radius (R) of each cell.

FIG. 5 shows the cellular system using the frequency reuse pattern described with reference to FIG. 4 with an additional tier of cells creating co-channel interference for a sector labeled sector 4

10   located in the middle of the diagram ("FIG. 5 target sector"). FIG. 5 shows the FIG. 5 target sector receiving co-channel interference from four cells, labeled A, B, C and D. This interference, in part, explains why the frequency reuse factor for a

15   conventional system using three sectors is typically K = 7.

In light of the foregoing, it can be appreciated that a substantial need exists for a cellular architecture that minimizes the co-channel interference

20   for adjacent sectors and cells, thereby decreasing the frequency reuse factor for a system, thereby increasing the overall capacity of the system.


SUMMARY OF THE INVENTION

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These needs and other needs are met by a method and apparatus for communications resource allocation in a wireless communications system having a total system bandwidth. A service area is divided into a plurality

30   sectors. A first set of base station antennas are positioned within a first set of sectors. The first set of antennas have main beams set at a first set of angles, and each antenna corresponds to a sector within

the first set of sectors.  A second set of base station
antennas are positioned within a second set of sectors
adjacent to the first set of sectors.  The second set
of antennas have main beams set at a second set of
5   angles, and each antenna corresponds to a sector within
the second set of sectors.  Each sector is assigned a
portion of the total system bandwidth.  This
arrangement decreases the frequency reuse factor to K =
2 while maintaining acceptable quality of service (QoS)
10  requirements.

      With these and other advantages and features of
the invention that will become hereinafter apparent,
the nature of the invention may be more clearly
understood by reference to the following detailed
15  description of the invention, the appended claims and
to the several drawings attached herein.

BRIEF DESCRIPTION OF THE DRAWINGS
20

      FIG. 1 is a diagram of a typical wireless
communication system suitable for practicing the
present invention.
      FIGS. 2(A) through 2(D) illustrate examples of
25  frequency reuse patterns corresponding to K = 4, 7, 12
and 19, respectively.
      FIG. 3 is a diagram of a conventional three-sector
cell.
      FIG. 4 illustrates a frequency reuse pattern with
30  K = 4 using conventional three-sector cells.
      FIG. 5 shows the cellular system using the
frequency reuse pattern described with reference to
FIG. 4 with an additional tier of cells creating co-

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channel interference for a sector labeled sector 4 located in the middle of the diagram.

FIG. 6 a three sector cell in accordance with one embodiment of the present invention.

5    FIG. 7 is a frequency reuse pattern using NBTC in accordance with one embodiment of the present invention.

FIG. 8(A) illustrates a first type of NBTC configuration referred to as "NBTC Type-I" in
10   accordance with one embodiment of the present invention.

FIG. 8(B) illustrates a second type of NBTC configuration referred to as "NBTC Type-II" in accordance with one embodiment of the present
15   invention.

FIG. 9 is a frequency reuse pattern of K = 2 using NBTC in accordance with one embodiment of the present invention.

FIG. 10 shows the cellular system of FIG. 9 with
20   an additional tier of cells creating co-channel interference for a sector using frequency set 1 located in the middle of the diagram.

25   <u>DETAILED DESCRIPTION</u>

The present invention comprises a cellular architecture and communications resource allocation method and apparatus that significantly reduces a
30   frequency reuse factor for a wireless communications system. The capacity of a conventional cellular system is inversely proportional to the frequency reuse factor (<u>i.e.</u>, K) for the system. A frequency reuse factor for

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conventional systems is typically K = 7. The present
invention reduces the frequency reuse factor to K = 2,
thereby tripling the capacity of many existing cellular
systems, while maintaining acceptable quality of
5    service (QoS) requirements.

A frequency reuse factor of K = 2 is achieved
using the following concepts. An advantageous
embodiment of the invention uses a narrow beam
trisector cell (NBTC) versus that of a wide beam
10   trisector cell (WBTC) used in conventional systems. A
NBTC uses an antenna for each sector having roughly
half the beamwidth used in a WBTC. The base station
antennas with smaller beamwidths used in a NBTC
generate an analytical cell contour that approximates
15   the hypothetical cell contour for each sector. NBTC,
therefore, decreases the amount of transmissions from
an originating sector that overlap into adjacent
sectors. In addition, this embodiment of the invention
uses sector rotation to decrease co-channel
20   interference between sectors. Sector rotation
minimizes co-channel interference from other cells.

The combination of sector rotation and NBTC yields
a frequency reuse factor of K = 2. This embodiment of
the invention utilizes a cluster of four cells, each
25   having three sectors. The total spectrum available to
the system is separated into 6 frequency sets. Each
frequency set is used for a single sector, and is
reused by a sector in an adjacent cell. As a result,
for every cluster of 4 cells, all 6 frequency sets are
30   used twice, thereby creating a frequency reuse factor
of K = 2.

Referring now in detail to the drawings wherein
like parts are designated by like reference numerals

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throughout, there is illustrated in FIG. 6 a three
sector cell in accordance with an embodiment of the
present invention.  As shown in FIG. 6, a hexagon is
used to represent the hypothetical contours of a sector
5    rather than an entire cell as in conventional systems.
The reason a hexagon is used to represent a sector
rather than the entire cell is because a base station
antenna may be selected that produces a main
transmission beam that better conforms to the shape of
10   a hexagon, rather than a diamond used in conventional
systems (as shown in FIG. 3).

More particularly, in this embodiment of the
invention, three hexagons are used to represent an
entire cell.  The hypothetical cell contours are
15   represented as solid lines.  The cell has a base
station located at the center, with a directional
antenna covering each sector of the cell.  The
beamwidth of each base station antenna is approximately
60 degrees, or roughly half of that used by
20   conventional systems.  The analytical cell contours are
represented by non-solid lines.  As shown in FIG. 6,
the analytical cell contours for the front lobe of the
antenna transmission beam for sector 1 forms the shape
of an oval.  Since the hypothetical cell contours for
25   sector 1 is in the form of a hexagon, the analytical
cell contours roughly approximate the hypothetical cell
contours.  As a result, it can be appreciated that the
analytical cell contours produce less interference for
adjacent sectors as compared to conventional systems
30   using WBTC.  This type of cell configuration is
referred to hereinafter as a narrow-beam trisector cell
(NBTC).

FIG. 7 is a frequency reuse pattern using NBTC in

accordance with a first embodiment of the present
invention.  As shown in FIG. 7, the distance (D)
between each NBTC base station is D = 2.6 radius (R),
which is less than the distance found in conventional

5   systems such as the one described with reference to
FIG. 4 (i.e., D = 3.5 R).  The decrease in D is a
result of the unique configuration of each NBTC which
utilizes a hexagon for each sector, thereby permitting
the interlocking hexagon sectors to fit close together

10  to create a "tighter" cell pattern.  The tighter cell
pattern increases the number of cells needed to cover
the service area of the system, which in turn increases
the number of times a frequency set may be reused,
thereby increasing the overall capacity of the system.

15       FIGS. 8(A) and 8(B) illustrate two types of NBTC
used in accordance with one embodiment of the
invention.  FIG. 8(A) illustrates a first type of NBTC
configuration referred to as "NBTC Type-I".  NBTC Type-
I is a cell having three sectors labeled sector 1,

20  sector 2 and sector 3, with each sector being serviced
by a directional base station antenna having angles on
the main beam of 30 degrees, 150 degrees and 270
degrees, respectively.  FIG. 8(B) illustrates a second
type of NBTC configuration referred to as "NBTC Type-

25  II".  NBTC Type-II is a cell having three sectors
labeled sector 1, sector 2 and sector 3, with each
sector being serviced by a directional base station
antenna having angles on the main beam of 90 degrees,
210 degrees and 330 degrees, respectively.  The

30  directional base station antennas all have a beamwidth
of approximately 60 degrees to 70 degrees, which is
approximately half the beamwidth of 100 degrees to 120
degrees used in conventional systems.

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It can be appreciated that the antenna angles for
NBTC-II are rotated clock-wise approximately 60 degrees
from the antenna angles used in NBTC-I.  This rotation
permits each cell to interlock and ensure complete

5    coverage of the service area while minimizing the
distance (D) between NBTC base stations, as discussed
in more detail with reference to FIG. 9.

     FIG. 9 is a frequency reuse pattern of K = 2 using
NBTC in accordance with a first embodiment of the

10   present invention.  This embodiment of the invention
utilizes a cluster of four cells labeled C1, C2, C3 or
C4.  Each cell has three sectors.  The total spectrum
available to the system is separated into 6 frequency
sets.  Each sector is assigned a single frequency set

15   from 1 to 6, with each frequency set being reused a
second time by a sector in an adjacent cell.  As a
result, for every cluster of 4 cells, all 6 frequency
sets are used twice, thereby creating a frequency reuse
factor of K = 2.

20       As shown in FIG. 9, in this embodiment of the
invention cell the sectors for cell C1 are assigned
frequency sets 1, 2 and 3, the sectors for cell C2 are
assigned frequency sets 2, 1 and 6, the sectors for
·cell C3 are assigned frequency sets 3, 5 and 4, and the

25   sectors for cell C4 are assigned frequency sets 6, 4
and 5.  The resulting pattern ensures that there is at
least one sector between sectors utilizing the same
.frequency set, thereby minimizing co-channel
interference between sectors.  This pattern also

30   ensures that each frequency set is used twice for every
cluster of 4 cells, and is repeated throughout the
service area for the system.  Therefore, on the
average, this embodiment of the invention makes every

two base stations utilize the whole spectrum, _i.e._,
K = 2.

     FIG. 10 shows the cellular system of FIG. 9 with
an additional tier of cells creating co-channel
5    interference for a sector using frequency set 1 located
in the middle of the diagram ("FIG. 10 target sector").
    FIG. 10 shows the target sector receiving co-channel
interference from three cells, labeled A, B and D. By
way of contrast, conventional systems using three
10   sector cells and wide-beam antennas (_i.e._, 120 degrees)
receive co-channel interference from at least four
other cells, as shown in FIG. 5. Thus, a cellular
system using NBTC receives less interference from other
cells within the system, thereby helping to achieve a
15   frequency reuse factor of K = 2.

     Although various embodiments are specifically
illustrated and described herein, it will be
appreciated that modifications and variations of the
present invention are covered by the above teachings
20   and within the purview of the appended claims without
departing from the spirit and intended scope of the
invention. For example, although specific angles for
the main beam of the base station antennas are given,
it can be appreciated that various angles fall within
25   the scope of the invention. Similarly, although ranges
of beamwidths for use with the base stations antennas
are given, it can be appreciated that any beamwidth
approximating the hypothetical cell contours given for
various embodiments of the present invention also falls
30   within the scope of the invention.

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What is claimed is:

1.    A method for communications resource allocation
for a wireless communications system having a total
5    system bandwidth, comprising the steps of:
          dividing a service area into a plurality of
sectors;
          positioning a first set of base station antennas
within a first set of sectors, said first set of
10    antennas having main beams set at a first set of
angles, and where each antenna of said first set of
antennas corresponds to a sector within said first set
of sectors;
          positioning a second set of base station antennas
15    within a second set of sectors adjacent to said first
set of sectors, said second set of antennas having main
beams set at a second set of angles, and where each
antenna of said second set of antennas corresponds to a
sector within said second set of sectors; and
20          assigning each sector in said first and second set
of sectors a portion of the total system bandwidth.


2.    The method of claim 1, wherein said first set of
angles are 30 degrees, 150 degrees and 270 degrees, and
25    said second set of angles are 90 degrees, 210 degrees
and 330 degrees.


3.    The method of claim 2, wherein beamwidths for said
first and second set of antennas are within a range of
30    50 degrees to 70 degrees.

4.    The method of claim 1, wherein said each angle of said second set of angles is 60 degrees apart from each angle of said first set of angles.

5    5.    The method of claim 1, wherein said first and second set of sectors each have three sectors, with each sector having a base station antenna.

6.    The method of claim 1, wherein said system has a
10    frequency reuse factor of K = 2.

7.    An apparatus for a wireless communications system having a service area divided into a plurality of sectors, comprising:
15        a first set of base station antennas within a first set of sectors, said first set of antennas having main beams set at a first set of angles, and where each antenna of said first set of antennas corresponds to a sector within said first set of sectors; and
20        a second set of base station antennas within a second set of sectors adjacent to said first set of sectors, said second set of antennas having main beams set at a second set of angles, and where each antenna of said second set of antennas corresponds to a sector
25    within said second set of sectors.

8.    The apparatus of claim 7, wherein said first set of angles are 30 degrees, 150 degrees and 270 degrees, and said second set of angles are 90 degrees, 210
30    degrees and 330 degrees.

9.    The apparatus of claim 8, wherein beamwidths for said first and second set of antennas are within a range of 50 degrees to 70 degrees.

5    10.    The apparatus of claim 7, wherein said each angle of said second set of angles is 60 degrees apart from each angle of said first set of angles.

11.    The apparatus of claim 7, wherein said first and
10    second cell each have three sectors, with each sector having a base station antenna.

12.    The apparatus of claim 7, wherein said system has a frequency reuse factor of K = 2.

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13.    A method for communicating signals over a wireless communications system having a service area divided into a plurality of sectors, comprising the steps of:
    communicating signals over a first set of base
20    station antennas within a first set of sectors, said first set of antennas having main beams set at a first set of angles, and where each antenna of said first set of antennas corresponds to a sector within said first set of sectors; and
25    communicating signals over a second set of base station antennas within a second set of sectors adjacent to said first set of sectors, said second set of antennas having main beams set at a second set of angles, and where each antenna of said second set of
30    antennas corresponds to a sector within said second set of sectors.

14. An apparatus for communications resource allocation for a wireless communications system having a service area divided into a plurality of sectors, and also having a total system bandwidth, comprising:

5      a first set of base station antennas within a first set of sectors, said first set of antennas having main beams set at a first set of angles, and where each antenna of said first set of antennas corresponds to a sector within said first set of sectors;

10      a second set of base station antennas within a second set of sectors adjacent to said first set of sectors, said second set of antennas having main beams set at a second set of angles, and where each antenna of said second set of antennas corresponds to a sector

15 within said second set of sectors; and

     means for assigning each sector in said first and second set of sectors a portion of the total system bandwidth.

20 15. An apparatus for a wireless communications system having a service area divided into a plurality of sectors, comprising:

     a switching network to provide switching for a plurality of base stations;

25      a first set of base stations operably coupled to said switching network for receiving signals over said network, said first set of base stations having antennas within a first set of sectors, said antennas having main beams set at a first set of angles, and

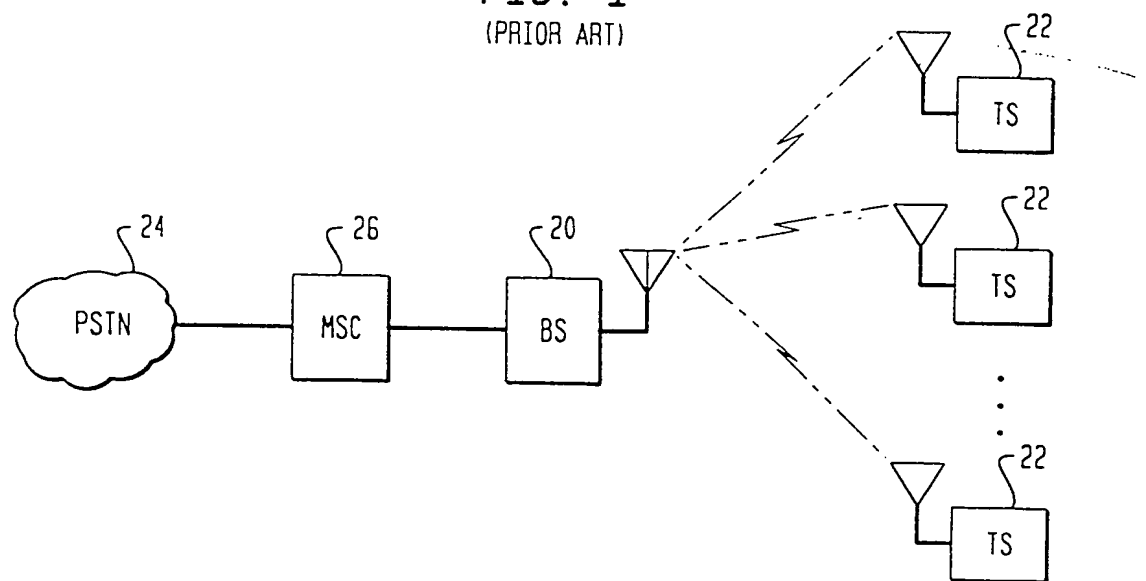30 where each antenna corresponds to a sector within said first set of sectors;

     a second set of base stations operably coupled to said switching network for receiving signals over said

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network, said second set of base stations having
antennas within a second set of sectors adjacent to
said first set of sectors, said antennas having main
beams set at a second set of angles, and where each
5    antenna corresponds to a sector within said second set
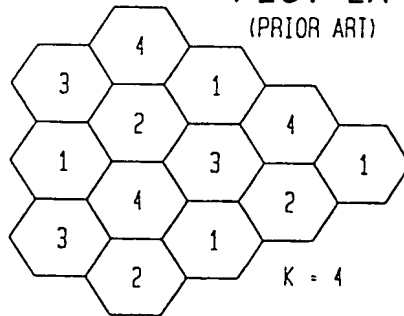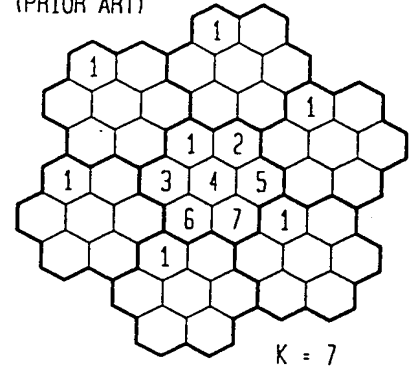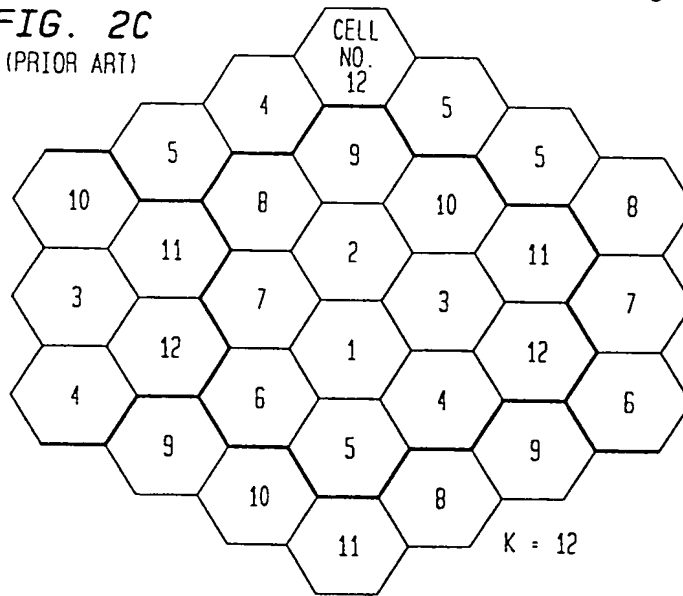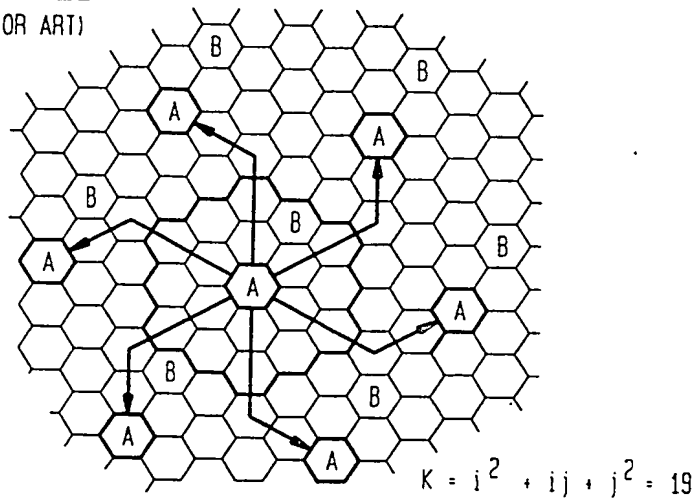of sectors; and

transceivers operably coupled to said antennas for
communicating said signals over said main beams for
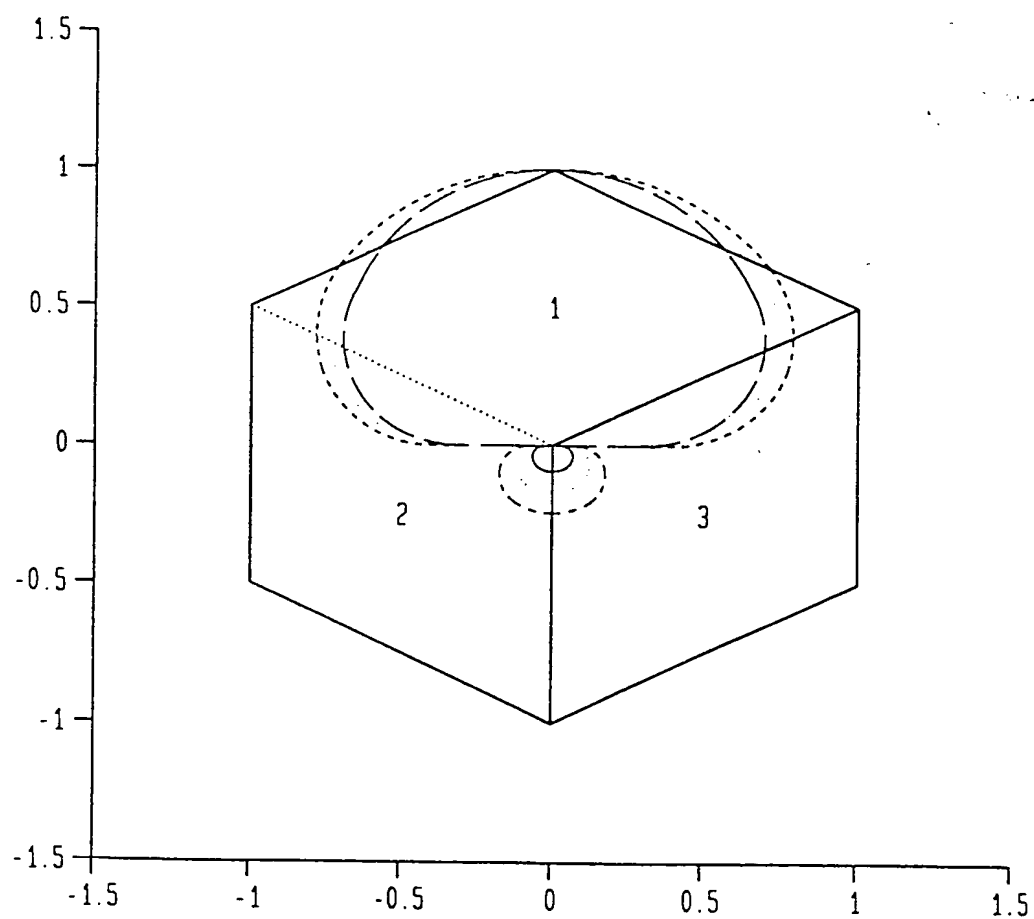said antennas.

FIG. 1
(PRIOR ART)

## FIG. 2A
(PRIOR ART)



K = 4

## FIG. 2B
(PRIOR ART)



K = 7

## FIG. 2C
(PRIOR ART)



K = 12

## FIG. 2D
(PRIOR ART)



$$K = i^2 + ij + j^2 = 19$$

## FIG. 3
### (PRIOR ART)

## FIG. 4
(PRIOR ART)
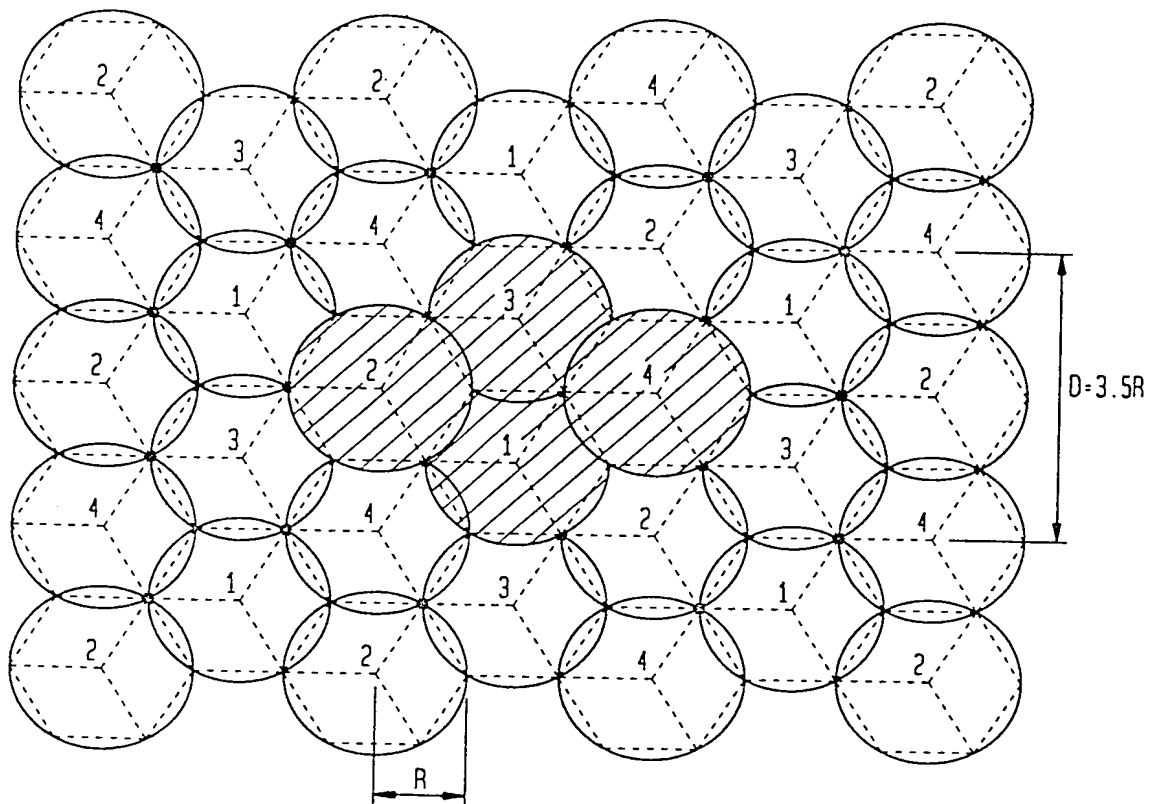
## FIG. 5
### (PRIOR ART)
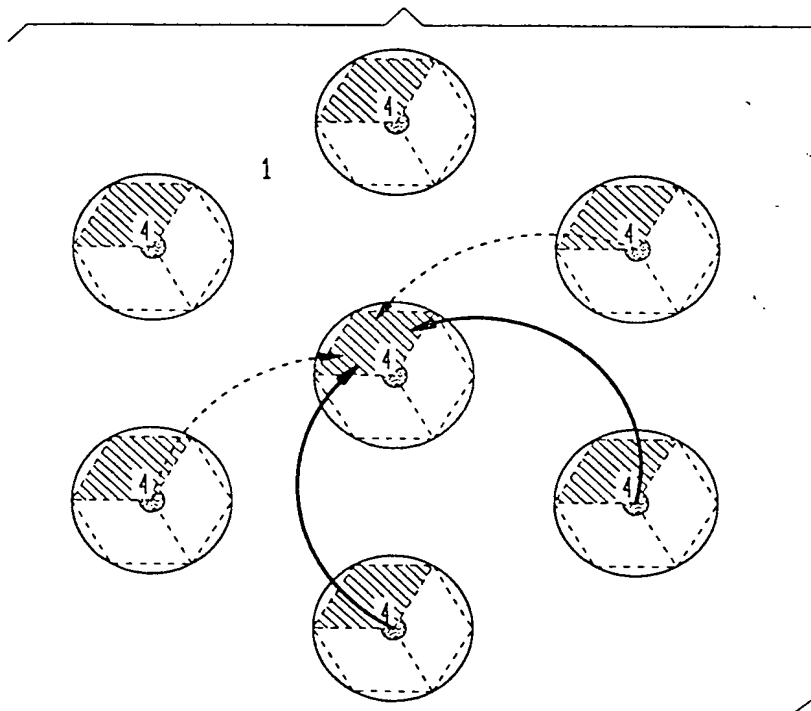


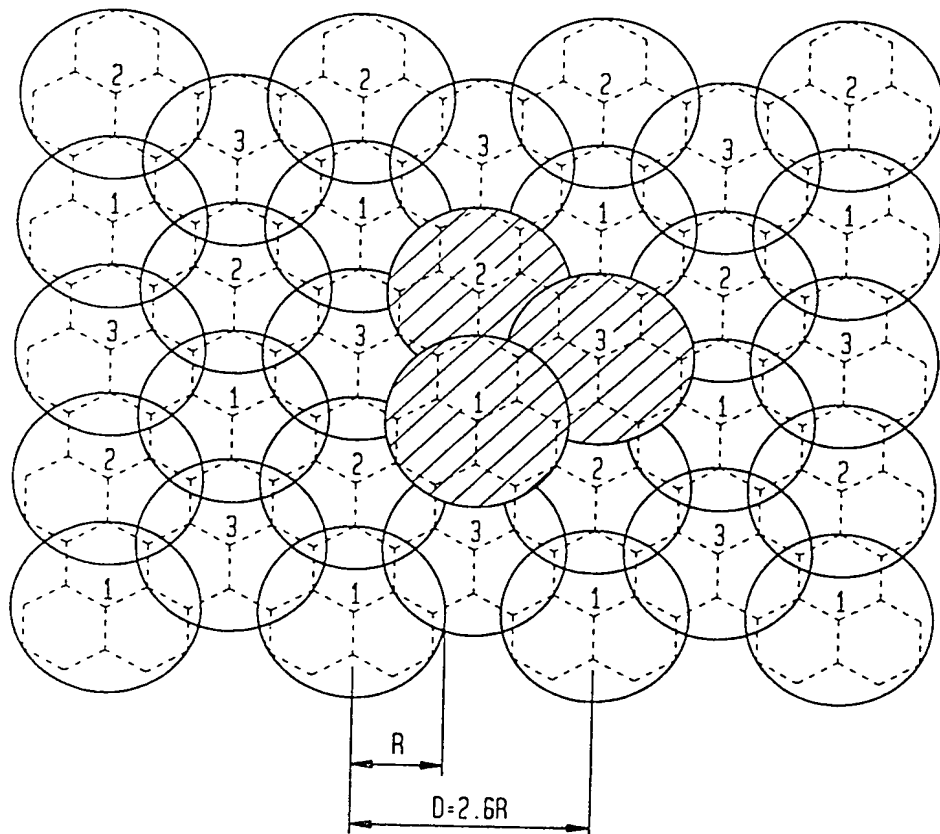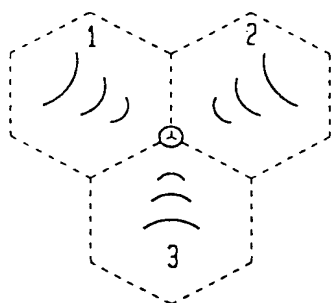## FIG. 6
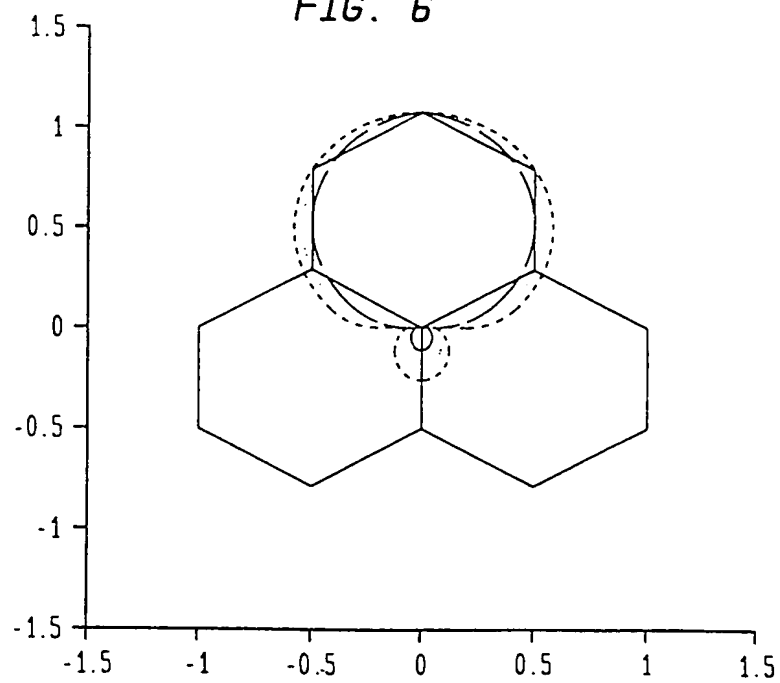
## FIG. 7

FIG. 8A



NBTC (TYPE-I)

FIG. 8B
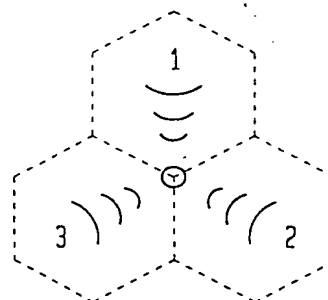


NBTC (TYPE-II)
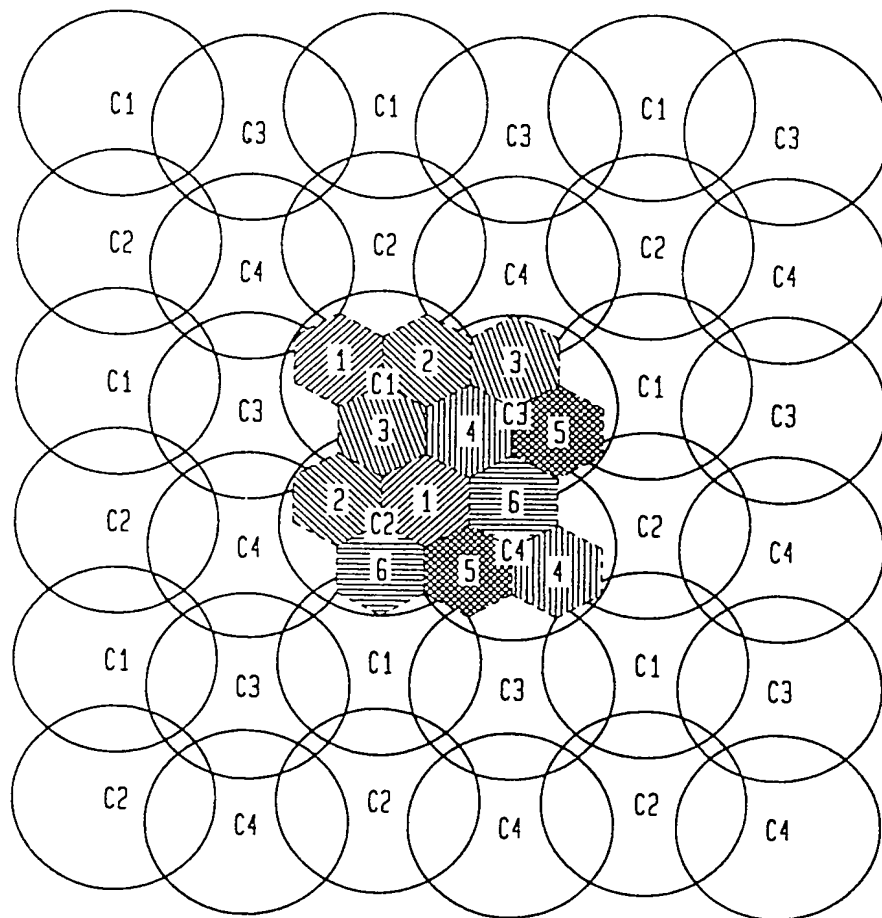
# FIG. 9
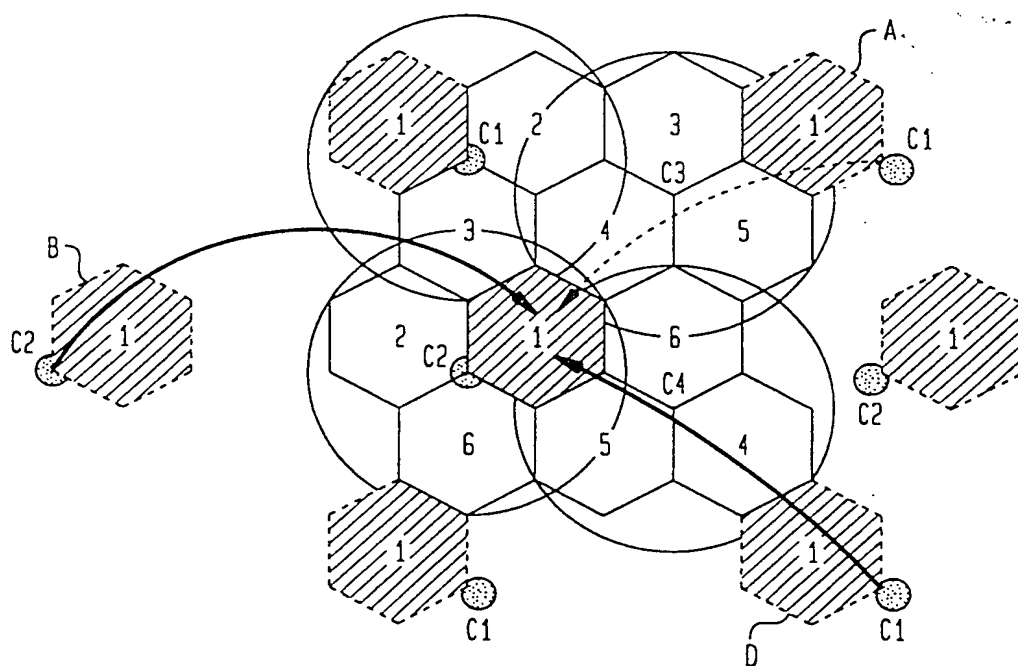
FIG. 10

# INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 H04Q7/36

According to International Patent Classification(IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimumdocumentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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[X] Further documents are listed in the continuation of box C

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| 27 October 1998 | 03/11/1998 |

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Masche, C |

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